CLAIMS

1. A device comprising:

   a) a three-dimensional perovskite compound layer, comprising a three-dimensional perovskite compound having a formula $(A^1)B(X^1)_3$ wherein:

      A^1 is selected from the group consisting of at least one ion of one or more group 1 elements of the Periodic Table of Elements, an organic cation having a structure of R^1-$(NH_x)_y^+$ wherein R^1 is CH or alkyl, x is 2 or 3 and y is 1 or 2, as valency allows, and any mixture thereof;

      B is at least one ion of one or more group 14 elements of the Periodic Table of Elements or any mixture thereof; and

      X^1 is a halide ion or any mixture thereof;

   b) a capping material layer comprising a capping material, provided on the three-dimensional perovskite compound layer, wherein the capping material is selected from a compound having a general formula $(A^2)_2M(X^2)_4$, $(A^2)_2(A^1)M_2(X^2)_7$, $(A^2)_mM_n(X^2)_{3n+m}$ or any mixture thereof, wherein:

      A^2 is an ammonium cation having a structure of R^2-NH_a^+ , wherein R^2 is an optionally substituted C_4 to C_{12} alkyl, an optionally substituted C_3 to C_{12} cycloalkyl, an optionally substituted arylalkyl, or any mixture thereof;

      M is at least one ion of one or more group 2, group 3, group 7, group 8, group 9, group 10, group 11, group 12, group 13 or group 15 elements of the Periodic Table of Elements, or any mixture thereof;

      X^2 is a halide ion or any mixture thereof;

      m is an integer of 1, 2, 3, 4 or 5;

      n is an integer of 1 or 2; and

      a is 0 or an integer of 1, 2 or 3.

2. The device according to claim 1, wherein A^1 is selected from the group consisting of $CH_3NH_3^+$, $CH(NH_2)_2^+$, Cs^+, Rb^+ and any mixture thereof, B is selected from the group consisting of Pb^{2+}, Sn^{2+}, Ge^{2+} and any mixture thereof, and X^1 is selected from the group consisting of I^-, Br^-, Cl^-, F^- and any mixture thereof.

3. The device according to claim 1 or 2, wherein the three-dimensional perovskite compound has the structure $Cs_{0.15}FA_{0.85}PbI_{2.8}Cl_{0.2}$, $Rb_{0.05}Cs_{0.10}FA_{0.85}PbI_{2.8}Cl_{0.2}$, or $Cs_{0.05}(FA_{0.83}MA_{0.17})_{0.95}Pb(I_{0.83}Br_{0.17})_3$, wherein MA is $CH_3NH_3^+$ and FA is $CH(NH_2)_2^+$.

4. The device according to any one of the preceding claims, comprising at least one of (a) to (d):

(a) wherein:

A^2 is selected from the group consisting of phenethylammonium (PEA) ion, n-butylammonium (BA) ion, iso-butylammonium ion, phenylmethylammonium (PMA) ion, 1-naphthylmethylammonium (NMA) ion, and any mixture thereof;

M is selected from the group consisting of Zn^{2+}, Pb^{2+}, Co^{2+}, Mn^{2+}, Cu^{2+}, Sb^{3+}, Bi^{3+}, Al^{3+} and any mixture thereof; and/or

X^2 is selected from the group consisting of Cl^-, Br^-, I^-, F^- and any mixture thereof;

(b) wherein the capping material layer has a β-K_2SO_4 type, β-K_2PO_3F type, cubic, orthorhombic or tetragonal single crystal structure;

(c) wherein the capping material layer is substantially free of Pb^{2+} or Sn^{2+}; and

(d) wherein the three-dimensional perovskite compound layer and the capping material layer are each independently annealed.

5. The device according to any one of the preceding claims, further comprising a hole transport layer comprising a hole transport material, wherein the three-dimensional perovskite compound layer is provided on the hole transport layer.

6. The device according to claim 5, wherein the hole transport material is selected from the group consisting of poly(triarylamine) (PTAA), poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS), (2-(9H-carbazol-9-yl)ethyl)phosphonic acid (2PACZ), [2-(3,6-dimethoxy-9*H*-carbazol-9-yl)ethyl]phosphonic acid (MeO-2PACZ), [4-(3,6-dimethyl-9*H*-carbazol-9-yl)butyl]phosphonic acid (Me-4PACz), (2-(3,6-dimethyl-9H-carbazol-9-yl)ethyl)phosphonic acid (Me-2PACz), NiO, CuSCN, CuO and any mixture thereof.

7. The device according to claim 5 or 6, further comprising an electrode, wherein the hole transport layer is provided on the electrode, preferably wherein the electrode is selected from the group consisting of indium tin oxide (ITO), fluorine-doped tin oxide (FTO) and any mixture thereof.

8. The device according to any one of the preceding claims, further comprising an electron transport layer comprising an electron transport material, provided on the capping material layer, preferably wherein the electron transport material is selected from the group consisting of C_{60}/bathocuproine ([6,6]-phenyl-C61-butyric acid methyl ester, BCP), methyl 4-[3′-phenyl-3′*H*-cyclopropa[1,9](C_{60}-I_h)[5,6]fulleren-3′-yl]butanoate (PC61BM), (6,6)-phenyl C71 butyric acid methyl ester (PC71BM), 1',1'',4',4''-tetrahydro-di[1,4]methanonaphthaleno[5,6]fullerene-C60 (ICBA), tin(IV) oxide, zinc oxide, and any mixture thereof.

9. The device according to claim 8, further comprising a counter electrode, provided on the electron transport layer, preferably wherein the counter electrode comprises an element selected from the group consisting of gold, silver, platinum, aluminium, copper, carbon and any mixture thereof.

10. The device according to claim 8 or 9, wherein the electron transport layer, the capping material layer, the three-dimensional perovskite compound layer and the hole transport layer are independently in a form of a film.

11. The device according to claim 9 or 10, wherein the counter electrode has a thickness in the range of about 100 nm to about 200 nm, the electron transport layer has a thickness in the range of about 45 nm to about 75 nm, the capping material layer has a thickness in the range of about 15 nm to 25 nm, the three-dimensional perovskite compound layer has a thickness in the range of about 400 nm to about 700 nm, the hole transport layer has a thickness in the range of about 20 nm to about 80 nm, and/or the electrode has a thickness in the range of about 150 nm to about 300 nm.

12. The device according to any one of the preceding claims, wherein the device is an optoelectronic device, photovoltaic cell, solar cell, light-emitting diode (LED), laser or photodetector, radiation detector, memristor, spintronic device, phototransistor, transistor, light emitting transistor (LET) or field-effect transistor (FET).

13. A method of preparing the device of any one of the preceding claims, comprising the steps of:

i) providing a three-dimensional perovskite compound layer, comprising a three-dimensional perovskite compound having a formula $(A^1)B(X^1)_3$ wherein:

A^1 is selected from the group consisting of at least one ion of one or more group 1 elements of the Periodic Table of Elements, an organic cation having a structure of R^1-$(NH_x)_y^+$ wherein R^1 is CH or alkyl, x is 2 or 3 and y is 1 or 2, as valency allows, and any mixture thereof;

B is at least one ion of one or more group 14 elements of the Periodic Table of Elements or any mixture thereof; and

X^1 is a halide ion or any mixture thereof;

ii) mixing a metal halide having a formula $M(X^2)_z$ with an ammonium halide having a formula $(A^2)(X^2)$ in a solvent to form a capping material solution, wherein

A^2 is an ammonium cation having a structure of R^2-NH_a^+, wherein R^2 is an optionally substituted C_4 to C_{12} alkyl, an optionally substituted C_3 to C_{12} cycloalkyl, an optionally substituted arylalkyl, or any mixture thereof;

M is at least one ion of one or more group 2, group 3, group 7, group 8, group 9, group 10, group 11, group 12, group 13 or group 15 elements of the Periodic Table of Elements, or any mixture thereof;

X^2 is a halide ion or any mixture thereof;

a is 0 or an integer of 1, 2 or 3; and

z is 2 or 3; and

iii) applying the capping material solution onto the three-dimensional perovskite compound layer to form a capping material layer comprising a capping material selected from a compound having a general formula $(A^2)_2M(X^2)_4$, $(A^2)_2(A^1)M_2(X^2)_7$, $(A^2)_mM_n(X^2)_{3n+m}$ or any mixture thereof;

wherein m is an integer of 1, 2, 3, 4 or 5; and

n is an integer of 1 or 2.

14. The method according to claim 13, comprising at least one of (a) to (e):

(a) wherein:

the metal halide having the formula $M(X^2)_z$ is selected from the group consisting of $Pb(X^2)_2$, $Zn(X^2)_2$, $Sn(X^2)_2$, $Co(X^2)_2$, $Mn(X^2)_2$, $Cu(X^2)_2$, $Sb(X^2)_3$, $Bi(X^2)_3$, $Al(X^2)_3$ and any mixture thereof;

the ammonium halide having the formula $(A^2)(X^2)$ is selected from the group consisting of phenethylammonium halide ($PEA(X^2)$), n-butylammonium halide ($BA(X^2)$), iso-butylammonium halide, phenylmethyl ammonium halide ($PMA(X^2)$), 1-naphthylmethylammonium halide ($NMA(X^2)$) and any mixture thereof; and/or

the solvent is selected from the group consisting of acetonitrile (ACN), acetone, dimethylformamide (DMF), dimethylsulfoxide (DMSO), methanol, t-butyl alcohol, ethanol, isopropyl alcohol, tetrahydrofuran, methylamine and any mixture thereof;

(b) wherein in the capping material solution, the metal halide having the formula $M(X^2)_z$ and ammonium halide having the formula $(A^2)(X^2)$ are present at a molar ratio in the range of about 1:1 to about 1:3;

(c) wherein in the capping material solution, the concentration of the metal halide having the formula $M(X^2)_z$ in the solvent is in the range of about 5 mM to about 50 mM;

(d) wherein the applying step comprises spin-coating, spray coating or slot-die coating the capping material solution onto the three-dimensional perovskite compound layer or dipping the three-dimensional perovskite compound layer in the capping material solution; and

(e) wherein the method further comprises the step of annealing the capping material layer onto the three-dimensional perovskite compound layer.

15. Use of the device according to any one of claims 1 to 11 in an optoelectronic device, photovoltaic cell, solar cell, light-emitting diode (LED), laser, photodetector, radiation detector, memristor, spintronic devices, phototransistor, transistor, light emitting transistor (LET) or field-effect transistor (FET).